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A Comparison of Mamdani and Sugeno Methods for Modeling Visual Perception Lab Data

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***Abstract* - A laboratory test procedure is described by the authors in which a baseline Light Armored Vehicle (LAV) is compared to a treated LAV in the TARDEC Visual Perception Laboratory (VPL). The test imagery was collected from the field and then adjusted for display in the laboratory. The experimental visual detection values obtained in the lab were modeled using the Mamdani and Sugeno/ANFIS Fuzzy Reasoning techniques. The results of each modeling approach are compared to the experimental detection values obtained in the laboratory.**

I. INTRODUCTION

Fuzzy Logic modeling of the data has been used before and shown to model the observed data with a 0.9 correlation. The benefit of using the FLA with vehicle and perception lab data is that the paradigm allows for making engineering level design changes to the vehicle or test environment within the Fuzzy User Interface and exploring the effect of these changes on the detection probability of the vehicle. Present first principle engineering level models cannot presently do this.

The LAV-25 was developed to provide the Marine Corps with enhanced mobile warfare capabilities. General Motors, Diesel Division in London, Ontario, Canada, began manufacturing the LAV FOV in 1982 and completed delivery to the USMC in April 1988. The LAV is a highly mobile vehicle for conducting reconnaissance, counter reconnaissance, limited offensive and defensive operations and other missions. Specifically, the purpose of this experiment was to determine the performance of a camouflage treatment in reducing the probability of detection in the visual part of the electromagnetic spectrum at various ranges, aspect angles and lighting conditions. Only the unclassified baseline results will be described in this report.

Mega-Pixel, high-resolution, digital cameras presently available on the market have come very close to equaling the resolution and color depth attainable with film. Six megabyte CCD imaging chips along with the ability to capture imagery in raw 24-bit format, combined with high capacity, portable, storage devices enable high-resolution imagery to be captured at field site locations and easily delivered back to the laboratory. The time consuming processing loop required with film has been removed. Using high-resolution graphics projectors, the imagery can then be presented in the controlled environment of a laboratory in such a manner as to obtain observer data with confidence levels approaching 99%. The benefits achieved using the repeatability and randomization offered by a lab environment are not available in a traditional field test.

II. EXPERIMENT

The images taken at the field site were prepared for the laboratory photosimulation test and then presented to thirty subjects. The experimental factors and levels with their values are shown below in Table 1. The photosimulation test in the lab was arranged so that the pixel Instantaneous Field-Of-View (IFOV) subtended by the monitors was less than one minute of arc and the displayed image represented with a unity magnification to the subject. The first test was meant to emulate naked-eye vision. Prior to the actual test, the subjects were instructed on the purpose of the test and given a pre-test in which they could become familiar with the imagery and software. None of the pictures used in the pretest were used in the actual test, however, the images were from the same set. The test protocol was to display an image with a time-out of thirty seconds. The imagery was cropped so that no scrolling was required. The target can appear within one of five possible regions. The soldier must use the mouse to "click-on" what he or she thinks is a target, based on the training. The tests are done in a dark room in which the subjects are 'dark-adapted' to maximize contrast differences in the images.

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Analysis of the first test showed most subjects obtained a score of only 20 % detection. This is reasonable given the difficulty of the imagery. The ranges are typical for such a test, however the high degree of clutter, and in particular, the height of the grass on the terrain makes it difficult for the unaided eye to detect common cue features of the vehicle. A second test was arranged to simulate closer ranges. The ability to resample the imagery is a feature of lab testing that would not be available on the field. Another benefit of the laboratory environment is that atmospheric effects can be added to the imagery for a more controlled simulation of atmospheric effects. Additional atmospheric effects were not added in this particular experiment, however, the capability does exit. The imagery from the field was of sufficient resolution so that there was no noticeable increase in pixelation of the imagery. The software used linear interpolation to zoom in on the selected imagery. The presentation in the lab was randomized for each subject.

Table I below shows the factors that were decided to be the most important for the test on the vehicle detection in the field. The chosen factors are; 1) Region of the field-of-view (FOV) in which the vehicle is present, 2) the range from the vehicle to the sensor, 3) the type of vehicle, 4) the aspect angle relative to the observer, 5) the lighting condition indicated by the position of the sun, front lit or back lit, and finally, 6) the general condition of the sky, clear or cloudy. In the vehicle type category, SLEP means the Service Life Extension Program, ADCAM is the trade name of the camouflage.

TABLE I
FACTORS FOR THE VISUAL DETECTION TEST

Target Location
Top-Left
Top-Right
Lower-Left
Lower-Right
Center

Range (km)
0.4
0.7
0.9
1.2
1.5
1.7
2.0
2.5
3.0

Vehicle Type
Baseline (old LAV)
SLEP + ADCAM
SLEP + ADCAM

Aspect angle
Front
30 degree
Side

Lighting
Front Lit
Back Lit

Weather condition
Clear
Overcast

The pictures below in Figures 1 through 6 were used for training observers as to what kind of vehicles they would be looking for in the test and also indicate some of the variables in the experiment such as vehicle type, treated or untreated, and aspect angle.

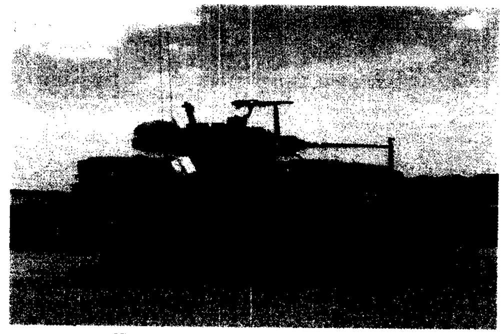

Fig. 1 Baseline side view

Fig. 2 Baseline front view

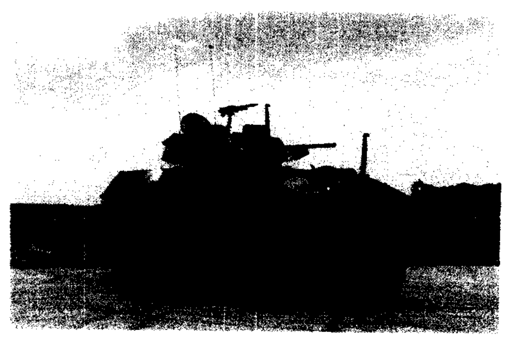

Fig. 3: Baseline 30 degree aspect angle

Fig. 4 Side view of ADCAM

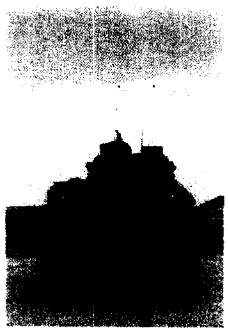

Fig. 5 Front view of ADCAM

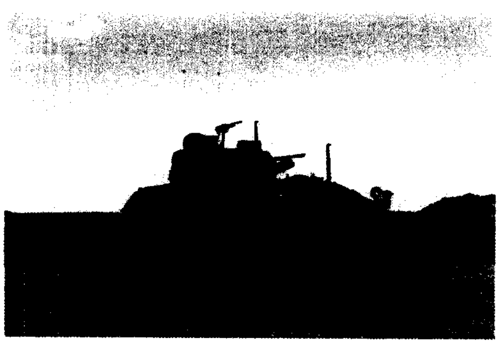

Fig. 6 ADCAM 30 degree side view

Figure 7 below is of the background at the field site and does not have a vehicle in it.

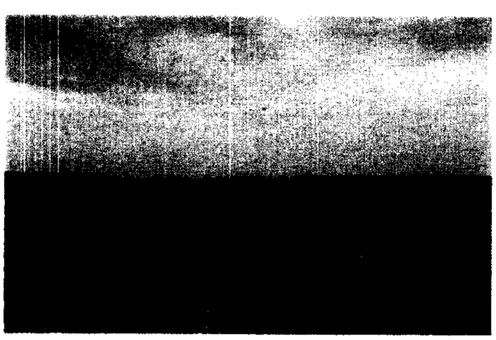

Fig. 7 Field test site

The picture shows that the grass height was high at the test site. The range of the test field was about 3.5 km and that the grass was high and obstructed the view of the vehicle at large ranges, thus requiring the simulation of powered optics by magnifying the images at certain amount depending on initial range.

III. ANALYSIS

Figure 8 below shows the averaged perception lab detection probabilities along with a logistic fit to the data. A logistic curve is the standard psychometric function used to model detection data. [1]

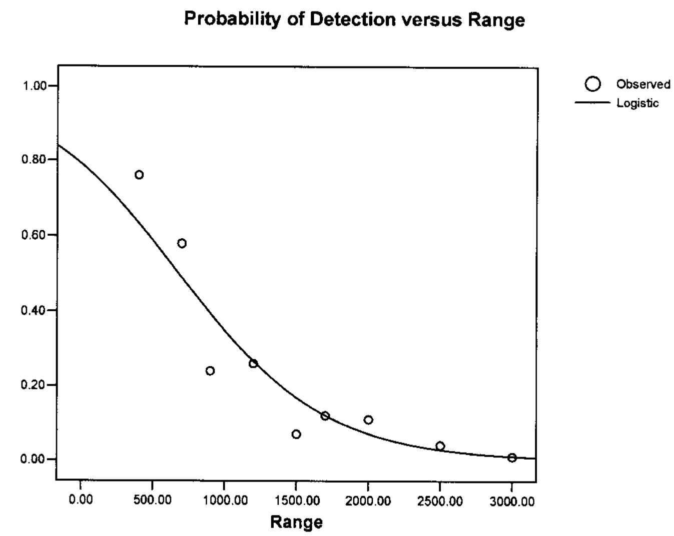

Fig. 8 Logistic curve fit to baseline vehicle lab data

IV: FUZZY LOGIC MODELING OF THE DATA

The Fuzzy Logic Approach (FLA) was used to model the experimental detection values to the imagery. The FLA and its application to modeling the probability of detection is described in other papers by the authors. [2, 3] The correlation obtained for Mamdani approach was 0.848 between the experimental values and the FLA model predicted value. The 0.848 correlation is between the model built from half the data set and the other half of the data was used for testing. Figures 9 to 11 show the several interfaces that are part of the Mamdani FLA model and that were designed by us based on our experience with similar data sets. [2, 3] The final output surface of the output value versus the inputs is shown in figure 12.

Figure 9 below shows the variables used in the construction of the 3-input, 1-output Mamdani Fuzzy Logic model. In Fig. 10 below the type of membership functions used to simulate the sky condition are shown, Gaussian bells in this case. When designing the fuzzy logic model the user can select one of several types of membership function. In this case, we chose to use gaussian bell membership functions.

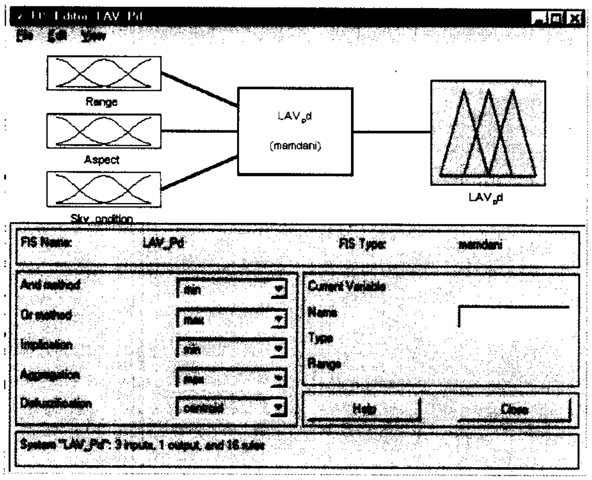

Fig. 9 Mamdani FLA Fuzzy Inference

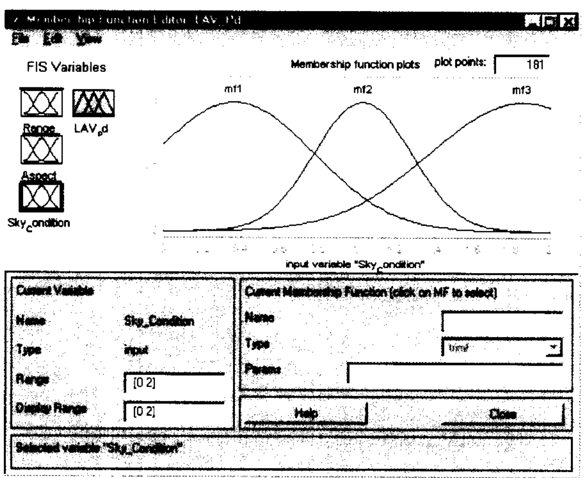

Fig. 10 FLA membership functions

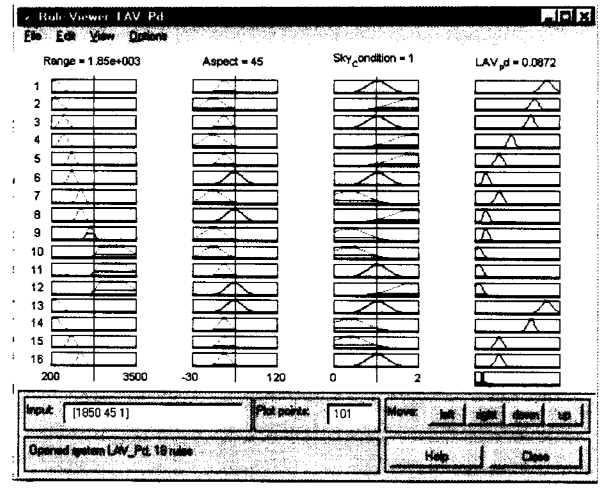

Fig. 11 FLA firing diagram

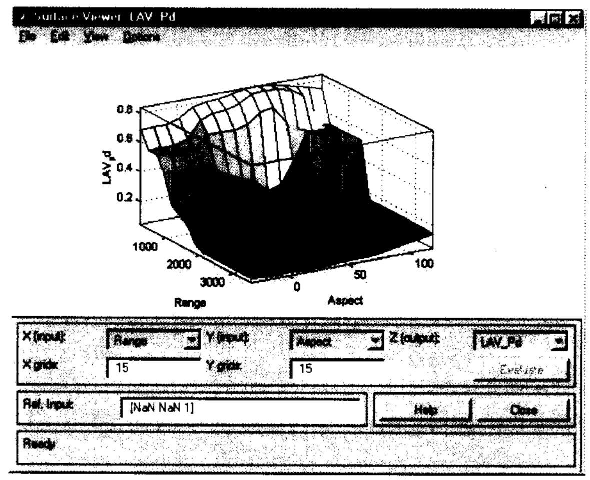

Fig. 12 Resulting model surface of probability of detection versus range and aspect angle

Once the membership function properties and the rule firing strengths have been coded into the model, the program then computes the firing strengths for the various rules and then sums up the results using the centroid method. The rule firings are shown above in Fig. 11. The final surface of the fuzzy logic system predicted probability of detection versus range and aspect angle is shown in Fig. 12 and a graph of the values used for input and the FLA output values are shown in Figure 13. A logistic fit to the detection values predicted by the Mamdani FLA is shown in Fig. 14. The lab data was also modeled using a Sugeno/ANFIS type Fuzzy Inference with correlations of 0.8400 and 0.65 using two and three membership functions respectively, as shown in Fig 's 15 and 16 respectively.

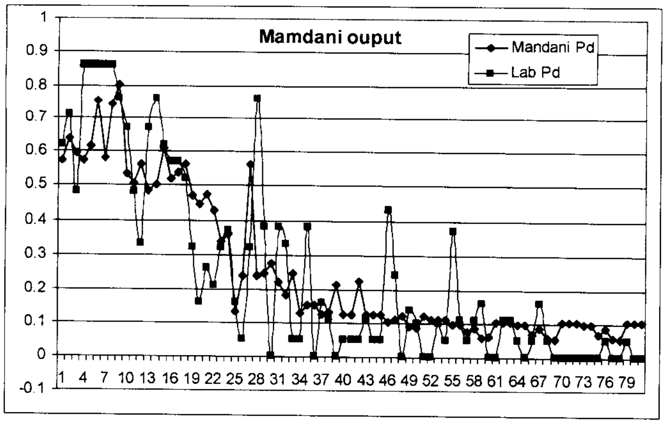

Fig. 13 Actual lab Pd and output Pd values for the Mamdani FIS, correlation = 0.848

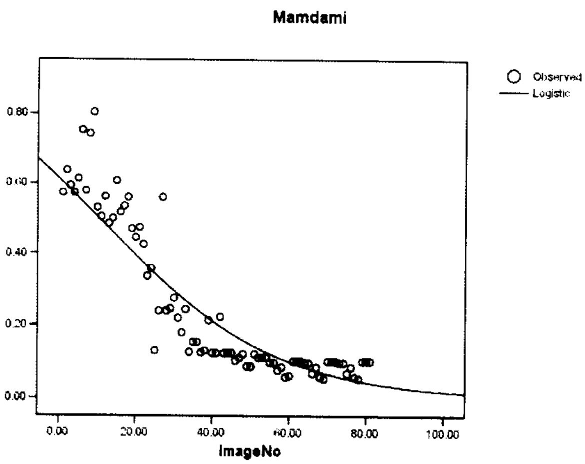

Fig. 14 Logistic fit to Predicted Pd's from Mamdani FIS

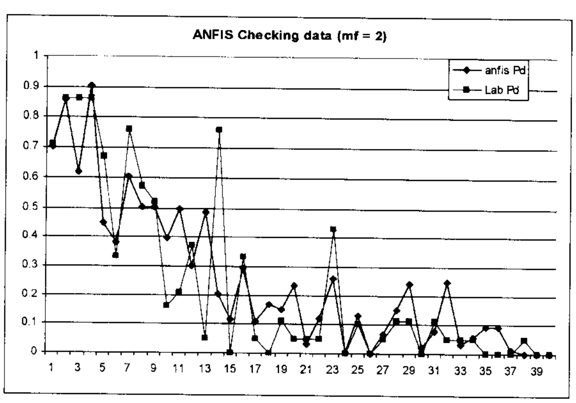

Fig. 15: Actual lab Pd and output Pd for the Sugeno/ANFIS using two membership functions, correlation = 0.84

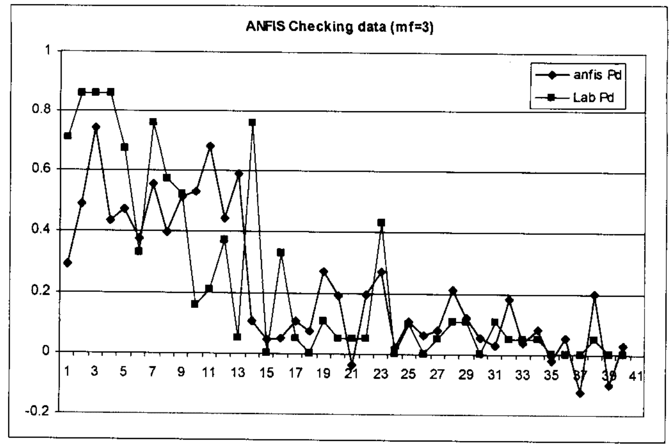

Fig. 16: Actual lab Pd and output Pd for the Sugeno/ANFIS using three membership functions, correlation = 0.65

V. CONCLUSIONS

In summary, an advantage of using the photosimulation lab environment is that experimenters are able to archive scenes used in the simulation, so that, at a later time it is possible to rerun the same image data set on a different subject pool. The new subjects may have different training and the images may also be modified by either magnification or adding atmospheric conditions. This provides tremendous cost savings since there is no need to pay for another field test.

Fuzzy logic models were constructed from the lab data that had 0.85 correlation to data not used in the training set. The Mamdani model proved to have the highest correlation to experimental data and permitted the easy variation and adjustment of the parameters. Future work will entail making a Fuzzy Inference System that will encompass a wider range of field conditions and vehicles.

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[3] T. Meitzler, H. Singh, L. Arefeh, E. Sohn, and G. Gerhart, "Predicting the Probability of target detection in static infrared and visual scenes using the fuzzy logic approach," Opt. Eng., Vol. 37 (1), Jan. 1998.